Adaptive Robot to Person Encounter

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Adaptive Robot to Person Encounter

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Introduction

How does a robot tell if a person is interested in interacting with the robot? How should the robot move when approaching a person showing interest in interaction? This poster concerns this spatial relationship between a robot and a person as shown in Fig 1.

A novel approach for adaptive movement control of the robot is developed based on the human to human proxemics described by Hall [1] (see Fig. 2). This control strategy is inspired by [2] and utilizes a cost function centred in the person.

The proposed method for determining if a person is interested in interaction, is based on a cognitive approach using Case Based Reasoning (CBR) [3].

The methods have been tested both in simulation and in a real world laboratory experiment, and have showed promising results.

Objectives

A robot to person encounter introduces the following problems, which are the objectives for this study :

- Detecting if the person is interested in interaction.
- How should the robot move when a person is interested?
- How should the robot move when the person is not interested?

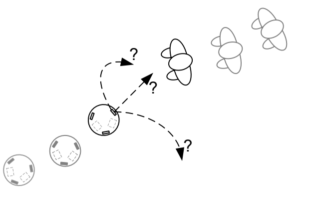

Fig. 1: A robot approaching a human for interaction – but is the person interested or not, and how should the robot move in either case?

Methods

Interaction interest: A person's willingness to engage in interaction is analyzed based on the person's spatial motion and based on knowledge from previous human-robot encounters. Motion primitives like a persons velocity, direction, distance to the robot is stored in a case database, and these cases are used to determine the interaction interest of the current person (see Fig. 3).

Control strategy:
An adaptive Gaussian person centred cost function is used to represent the desired spatial behaviour of the robot, allowing the knowledge about social interaction described by hall zones [1], to be taken into account. The cost functions are adaptive and adjusted by the person's interest in interaction, allowing the robot to move into the person's personal zone at a 45 degree angle in case interaction interest is expressed. The cost function is a weighted summation of four bivariate Gaussian distributions shown in Fig. 4, and examples are shown in Fig. 5:

$$f(\vec{x}) = v_i \sum_{i=1}^{4} \frac{1}{(2\pi)|\Sigma_i|^{1/2}} \exp\left(\tfrac{1}{2}\vec{x}^T \Sigma_i^{-1} \vec{x}\right)$$

where v_i is the weight assigned to each Gaussian cost function, and the width and orientation of the cost functions are determined by:

$$\Sigma_i = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^2 \end{bmatrix} \qquad \tan(2\theta) = \frac{2\sigma_{xy}}{\sigma_x^2 - \sigma_y^2}$$

Distributions:

Attractor: Is a circular negated distribution used to attract the robot towards the person.
Rear: Prevents the robot from passing behind the person.
Parallel and perpendicular: Makes sure that the robot approaches from the right direction.

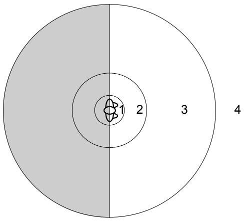

Fig. 2: *The Hall zones in the area of a human:*
Zone 1: Intimate Zone, < 0.45 m
Zone 2: Personal Zone, 0.45 – 1.2 m
Zone 3: Social Zone, 1.2 – 3.6 m.
Zone 4: Public zone, > 3.6 m

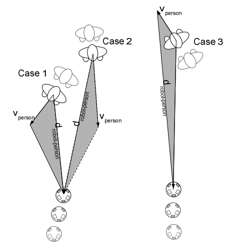

Fig. 3 *Illustration of the variables; distance, area and position used for input to the CBR database.*

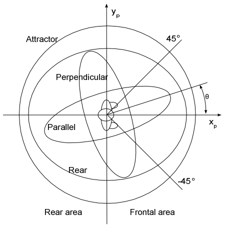

Fig. 4 *Illustration of the four Gaussian distributions used for the cost function around the person.*

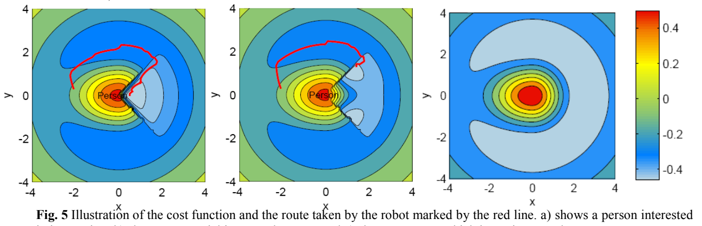

Fig. 5 Illustration of the cost function and the route taken by the robot marked by the red line. a) shows a person interested in interaction. b) shows a potential interested person, and c) shows a person which is not interested.

Experiment and Results

Experiments have been done both in simulation and in real world. The simulation tests the capability of the Case Base Reasoning module, and the real world experiment tests the movement pattern of the robot. The simulation has been done using the robotic software framework *Player/Stage*, and the real world experiment has been done using a FESTO Robotino® robot platform equipped with a laser range finder and a camera for detecting persons. In the simulation an extra simulated robot was used to represent a person. Experiments were made with persons both interested and not interested in interaction.

Simulation: Results from the simulation is shown in Fig. 6. The left column shows the behaviour with an untrained database for both an interested and a not interested person. After this, the CRB database was trained with 20 series including 10 interested and 10 not interested persons. The results with at trained database is shown in the right column. For the interested case, it is seen that the robot is much slower to start interaction, and even reverses a little (Fig. 6a). For the not interested person, the trained database makes the robot much faster realize the situation and starts to move away from the person again.

***Real world experiment*:** Results from the physical experiments are shown in Fig. 7. In this experiment the robot CBR database is not trained, but is given prior information about the person's interest. In a) and b) the pose of the person is indicated by moving forward towards the person, and in c) and d) the pose is not indicated, which makes the robot think it comes from behind the person. In the left column the person is not interested in interaction, and it is seen that the robot is repelled. In the right column the person is interested, and it is seen that the robot is attracted towards the person. Comparing the top row to the lower row, it is seen that the robot moves around the person to get in front of the person.

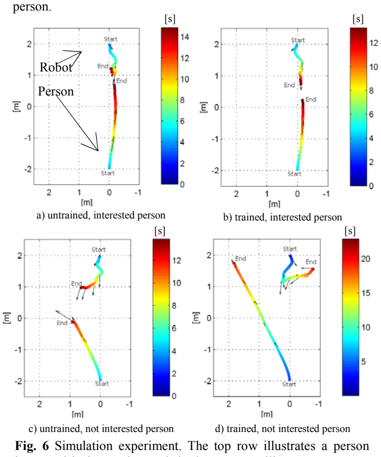

Fig. 6 Simulation experiment. The top row illustrates a person interested in interaction and the bottom row illustrates a person not interested. The left figures shows results from an untrained database, and the right from a trained database.

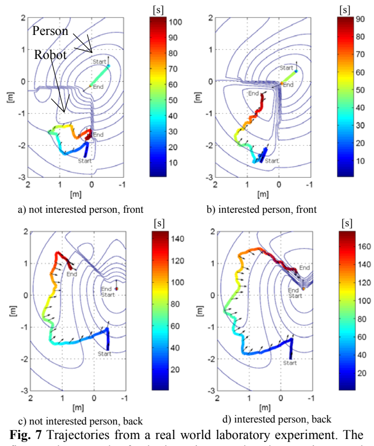

Fig. 7 Trajectories from a real world laboratory experiment. The figures show results for both an interested and a not interested person either with the front or the back towards the robot. The contours illustrates the cost function at the end of the experiment.

Discussion

The real world test results demonstrates how an adaptive Gaussian cost function may be used as the basis for a spatial robot behaviour scheme. Furthermore simulations show a proof of concept that a Case Based Reasoning (CBR) database can be utilized to incorporate learning capabilities of the robot. The CBR module needs further testing and development. It could be extended with information about robot velocity or e.g. speech or gesture recognition. Furthermore a limitation of the current system is that it relies on the pose of the persons, but if the persons is standing still, it is not possible to know which side to approach from. The real world experiments are quite limited to a few scenarios without use of the CBR module. This needs further and more extensive testing also.
Although these limitations, the simulation and experiments has shown a proof of concept that a summation of adaptive Gaussian cost functions can be used to control the motion of a robot in human interaction. Additionally it has been demonstrated that CBR can be used to implement cognitive abilities on a robot for human interaction.

References

[1] E. Hall. *The Hidden Dimension.* Doubleday, 1966
[2] E. A. Sisbot, R. Alami, T. Simeon, K. Dautenhahn, M. Walters, S. Woods, K. L. Koay, and C. Nehaniv. *Navigation in the presence of humans.* In IEEE-RAS International Conference on Humanoid Robots, Tsukuba, Japan, December 2005
[3] A. Ram, R. C. Arkin, K. Moorman, and R. J. Clark. *Case Based reactive navigation: A case-based method for on-line selection and adaptation of reactive control parameters in autonomous robotic systems.* IEEE Transactions on Systems, Man and Cybernetics, 27:376-394, June 1997

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